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1978 S S YEANDLE, H BASSEN, J R THOMAS
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The details are shown of a small inexpensive microwave irradiation chamber for exposure of rats to 2450 MHz radiation used in studies of the behavioral effects of microwave radiation. The spatial variation of the magnitude of the electric field vector and absolute calibrations of the field within the chamber are reported. During irradiation the rat was constrained in a plastic sleeve suspended from a wooden frame placed one to two feet from a horn antenna which projected the radiation into the chamber. Although the variation of the field was large over the body of the rat, it was small over the head which is presumably the site of action of microwave induced behavioral effects.

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During the past several years a number of investigators at the Naval Medical Research Institute have been studying the effects of 2450 MHz pulsed microwave radiation on the conditioned behavior of rats (1, 2, 3). As part of this program studies where pharmacological agents and microwave radiation are administered simultaneously have indicated a synergism between low intensity microwave radiation (approximately 1 mW/cm^2) and tranquilizing drugs. Because of the potential importance of these results, we provide documentation of the microwave chamber used in all of the near-field exposures. This report describes the chamber, the method of measuring the field used for exposures, and some measurements performed at the Bureau of Radiological Health of the spatial variations within the chamber of the electric field magnitude of the 2450 MHz radiation.

The chamber consisted of a wooden frame upon which rectangular blocks of microwave absorber were placed (see Fig. 1). The absorber was Eccosorb FR 340 made by Emerson and Cumming, Canton, Mass. Reflection of 2450 MHz radiation from this absorber is rated at 20 db.

For exposure to radiation the rat was placed in a sleeve of fine plastic netting, the ends of which were tied with string so the rat could not move, the harness hung from a wooden frame, and the frame placed in the chamber so the rat's head lay along the boresight (axis of propagation) of a horn antenna placed at the mouth of the chamber (see Fig. 1). Duration of each exposure was 30 minutes. The horn, which projected microwave radiation into the chamber, was a standard gain horn, model 299 made by Waveline, Inc. of Caldwell, N. J. and was designed to be operated in the range of 2.6 to 3.95 GHz. Hence it was slightly mismatched to the 2.45 GHz radiation used in the behavior studies. The horn was fed by a model PH40K pulse microwave generator with a plug-in module 1708H manufactured by Epsco Applied Microwave, Inc., Westwood, Mass.

A 30 db directional coupler was inserted in the transmission line leading from the generator to the horn to allow sampling of the power by a Hewlett-Packard power meter type 432A so that any changes in the power output during an experiment could be compensated by adjustment of the power control on the microwave generator. The power generator produced pulses of microwaves of variable repetition rate and pulse duration by switching on and off the supply voltage to a resonant cavity oscillator. A fraction of this voltage was fed to a 450 MHz band-pass oscilloscope (Tektronix type 475) which enabled one to monitor pulse duration and repetition rate. The precise wave shape of the pulse at the position of the rat's head was not determined as the requisite detector was not available to us.

Let $|E|^2$ be the magnitude squared of the electric field of the radiation. With the rat removed from the chamber, the time averaged $|E|^2$ of the radiation used for exposure was determined with a Narda isotropic probe (model 8321 with a model 8310 readout) placed at the point in the chamber occupied by the rat's head during irradiation. Absolute calibration of the probe was done with plane wave radiation by both the Narda Corporation and the Bureau of Radiological Health. The two calibrations were within 10% of each other and were given as an equivalent power density in units of mW/cm^2 even though the probe essentially measures the time averaged $|E|^2$. The probe is designed to measure the field of plane waves where the ratio of $|E|^2$ to power density is a constant. Most of the exposures of the rat were done between one and two feet from the horn where the radiation is not precisely a plane wave so that the ratio between $|E|^2$ and power density may be slightly different from the plane wave case. We ignored this and expressed all calibrations in mW/cm^2 as read from the meter of the probe. When used, the probe was always at the same orientation with respect to the electric field vector as during the absolute calibration.

For measuring field strength in the chamber the probe was mounted on a wooden arm that passed through a slot in the middle of one side of the chamber and that was attached to a stand on the outside of the chamber. The stand, which also held the model 8310 readout, could be moved along the side of the chamber. This arrangement allowed placing the probe at the positions of the rat's head.

Relative spatial variation of $|E|^2$ in the chamber was measured with a high resolution probe developed at the Bureau of Radiological Health (4). This probe consisted of 3 dipole antennae, each approximately 3 mm long, oriented mutually perpendicularly to each other and mounted on a plastic holder which only slightly perturbed the field. Integrated electronics, mounted at the base of the plastic holder, amplified the rectified signals from the antennae and transmitted them as frequency modulated light pulses over fiber optic bundles to photodetectors and demodulators located outside the chamber where the signals were converted to three D.C. voltages proportional to the square of the amplitude of the three components of the electric field vector (for a complete description, see (4)).

The probe was introduced in the side of the chamber through a slot running along the middle of one side of the chamber. Two wooden arms connected by a movable joint allowed one to position by hand the probe at any position in the chamber. Motorized drives, located outside the chamber and to which the system of arms was connected, allowed the probe to be moved linearly with time along any horizontal line either normal or parallel to the long side of the chamber. The field along a line was recorded on an X Y plotter whose X axis was driven by a linearly time dependent voltage and whose Y axis was driven by the probe output.

Since the BRH probe was designed to measure non-pulsed continuous radiation, the horn was powered by a 2450 MHz CW generator during all

measurements of spatial variation of electric fields. The output of the CW generator was monitored through a directional coupler and Hewlett-Packard power meter inserted in the transmission line leading from the generator to the horn. Throughout all measurements the output of the generator was kept constant. The horn was oriented so that, according to theory, the E field was vertical everywhere except within a few inches of the horn, and this was found experimentally to be true. No exposures of animals occurred where an appreciable horizontal component existed.

Figure 2 shows the relative value of $|E|^2$ along a line between the center of the horn and the rat's head and long lines immediately adjacent and parallel to the rat between the horn and the rat. Illustrated are plots of $|E|^2$ as a function of distance. The maximum in Figure 2B and 2C are along the boresight of the antennae. Scans of $|E|^2$ were made with and without the rat being present.

From the figures the following is evident: (1) The variation in the field in the absence of the rat over the space occupied by the rat's head was not very great (about 10%) even though the field over the entire rat's body varied greatly (as much as 50%); (2) in the absence of the rat, standing waves, although noticeable, were not large; (3) when the rat was present, because it is a conducting body of complicated shape, the field was distorted and large standing waves were set up in front of the rat.

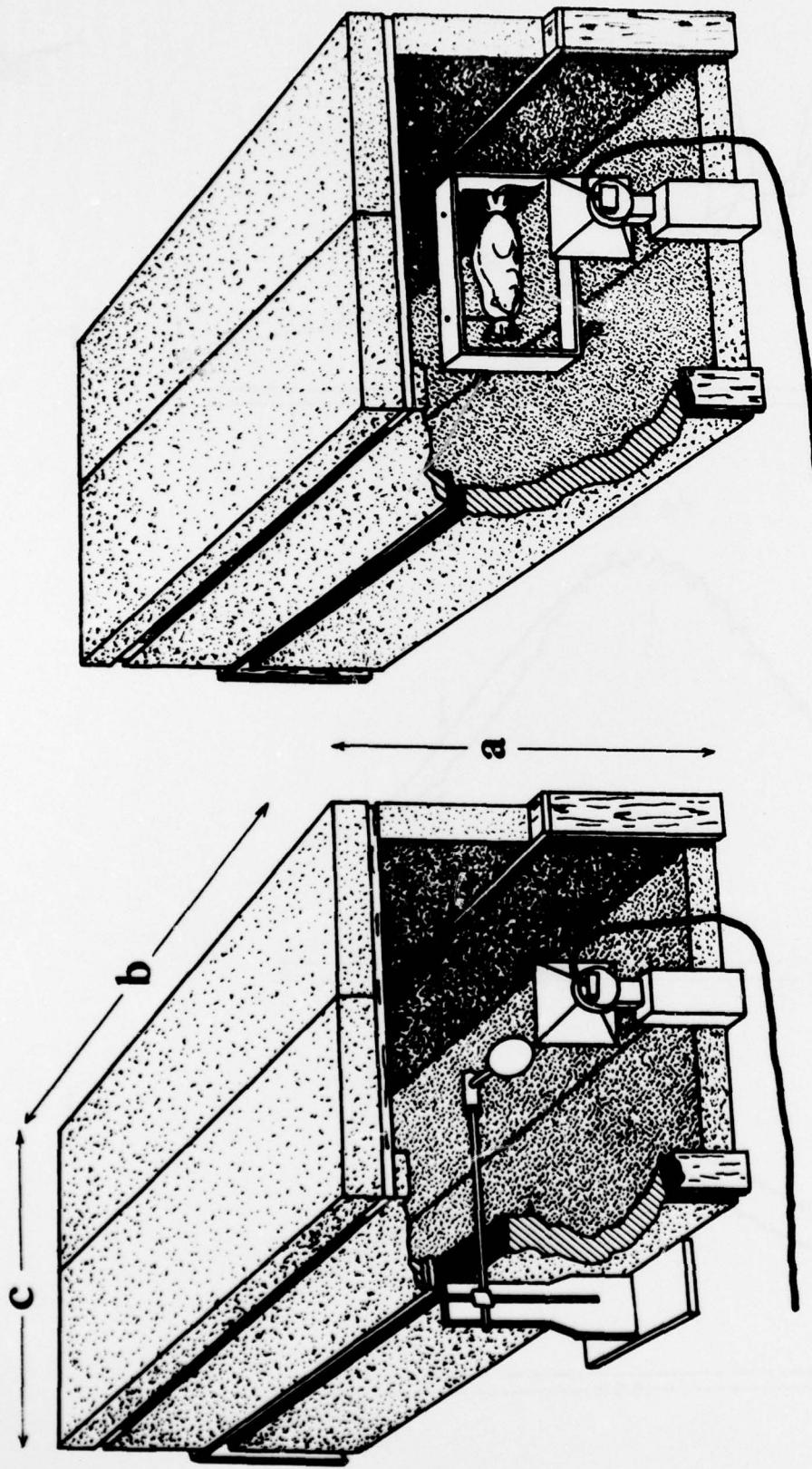
What is of most interest and what these measurements say nothing about is the variation of the electric field within the rat's head. This could be quite complicated as the diameter of the rat's head is similar in magnitude to the wavelength of the radiation within the rat's head (about 1.7 cm). The problem of intracranial measurements of $|E|^2$ has been addressed by

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Bassen et al. (5) and a smaller probe than that used in the present study has been developed. Such small probes may in the future be used to measure $|E|^2$ intracranially in small animals such as the rat.

Fig. 1



Drawing on left shows wooden frame upon which FR 340 Eccoisorb is placed. Narda probe is mounted on arm attached to movable slide and positioned along side of chamber. Distances a, b, c, the dimensions of the chamber, are respectively 34.5", 48", and 24". Drawing on right shows rat wrapped in nylon sleeve and suspended from wooden frame. Head of rat along boresight of the antenna.

FIG. 2A

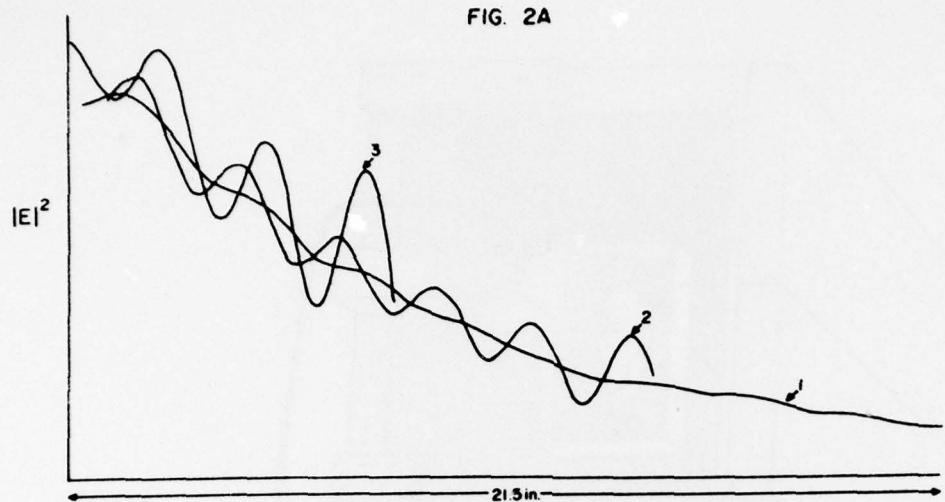


FIG. 2B

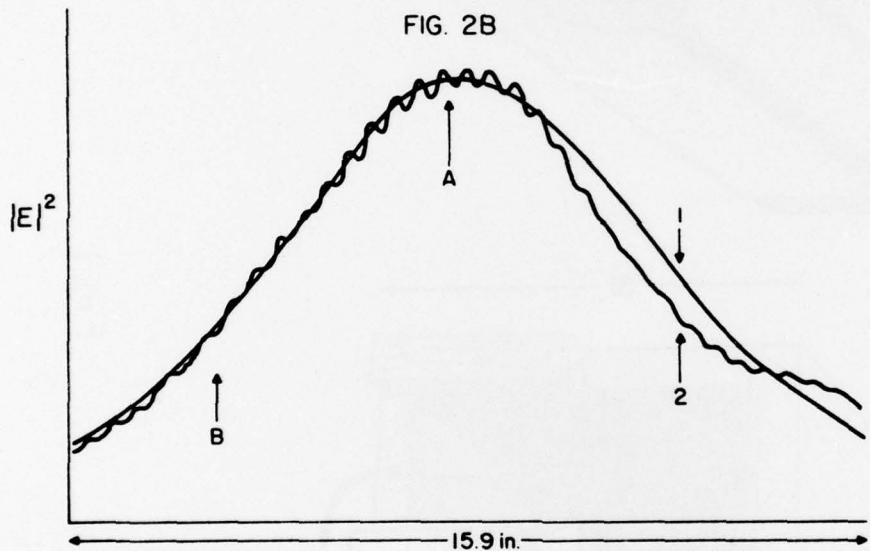


FIG. 2C

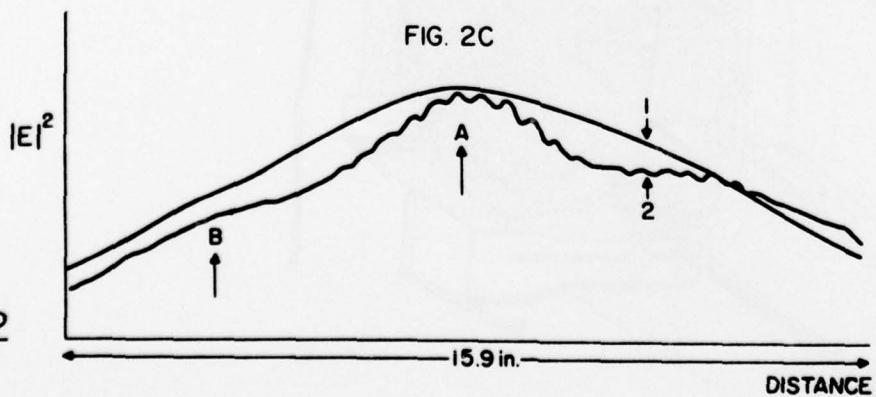


Fig. 2

Fig. 2A. Plot of relative value of $|E|^4$ on an arbitrary linear scale as measured by BRH probe along boresight of horn antenna, i.e., along a line that traverses the center and is normal to the plane of the horn opening. Curve 1 is when no rat is in chamber, curve 2 rat is 18 inches from the horn, and curve 3 rat is 12 inches from the horn. Curves 2 and 3 stop less than an inch in front of the rat. Zero point of abscissa is approximately 4 inches from horn.

Fig. 2B. Plot of relative value of $|E|^2$ on an arbitrary linear scale along a line that is parallel to the rat and perpendicular to the axis of the horn. The line occurs, within an inch of the location of the rat, between the horn and the antenna when the rat is 12 inches from the horn. Curve 1 is field when rat is removed from the chamber, and curve 2 is field when rat is 12 inches from the horn. A indicates location of center of rat's head, and B indicates base of his tail.

Fig. 2C. Plot of relative value of $|E|^2$ on an arbitrary linear scale along a line that is parallel to the rat and perpendicular to the axis of the horn. The line occurs within an inch of the location of the rat between the horn and the antenna when the rat is 18 inches from the horn. Symbols 1, 2, A, and B have same meaning as in Fig. 2B.

FIGURE 2 LEGENDS